OPTIMIZED PRODUCTION OF COMPLEX SHAPE OPTICAL COMPONENTS VIA PRECISION GLASS MOLDING

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Instructions
Our everyday life is associated with many leading edge technologies, like automotive industry, laser technology and life science. The key position for the improvement of these technologies is the production of required complex shaped optical components, as spheres, aspheres and arrays, with high accuracy. For example, for the high performance diode laser, fast axis or slow axis collimation lenses with high precision are required. With this lenses the light beam from the emitter is collimated, thereby the beam divergence is reduced and the beam quality is increased [2,3].

One promising manufacturing process of such components is the precision glass molding. Different to conventional machining technologies like grinding and polishing, the glass parts are formed in one process step. After heating up the raw parts, the glass is pressed under load into its final shape[1].

Due to different thermal expansion of mold and glass material, the final shape of the glass differs from the mold shape after the molding process. In this paper, investigations into the with Finite element analysis (FEA) of optimized production of complex shaped optical components will be presented. With the use of the simulation the glass shrinkage can be calculated without any try out molding activities. On the basis of this simulation result, this shrinkage can be directly compensated by mold manufacturing. So the time and cost consuming iteration can be eliminated.

Process Chain for Production of Complex Shaped Optical Components via Precision Glass Molding
One advantage of the production of complex shaped optical components via precision glass molding is that, the designated lens is formed to its end shape in one molding cycle. These produced lenses are ready to use so that further time consuming finishing processes are not required. So the production of complex shaped optical components is more efficient compared to the conventional production method, which includes grinding and polishing. Another advantage of this production method is that, complex shaped optical components with high geometrical complexity can be produced with high form accuracy.

The process chain for production of complex shaped optical components consists of four main steps [5] (Fig. 1):
- Design
- Mold making
- Molding
- Measurement

FIGURE 1 Process chain for manufacturing complex shaped optical glass components

The design step includes three sub-steps (Fig. 2). First of all the lens design has to be made. With the lens design the lens dimensions, specifications and quality are defined. After the lens design the glass shrinkage, the actual inserts and glass temperature are calculated by means of finite element analysis. These
calculated data are transported to the next sub-step, insert design. The insert can be finished in consideration of the glass shrinkage, so some pre glass molding steps to determinate the glass shrinkage are not required. Also a reengineering of the insert to achieve high form accuracy by the molded lenses can be eliminated by the usage of the FEA.

After the mold making the lens can be molded via precision glass molding. In this process the insert and also the glass blank are heated up to the molding temperature and the glass blank is pressed to its end shape. After this molding process the ready to use lenses can be installed in optical system.

The final step of the process chain for the manufacturing of complex shaped optical components is the measurement. Two main quality criteria of the inserts and the lenses are the roughness and the form accuracy. Form accuracy can be used to measure the roughness. The form accuracy is checked in many cases with a tactile measurement device.

**Finite Element Analysis of Molding Process**

The FEA of the presicion glass molding process is accomplished on the basis of three models:

- Thermal model
- Structural model
- Multi-physics model

With the heat model the heat transmission of the molding process is analyzed. Meaning the heat transmissions from infrared lamps to the inserts, to the glass and the heat transport between glass and insert are considered with different heat transfer principles, conduction, convection and radiation. To implement the structural simulation, the boundary conditions are predefined with the structural model. In this model the viscoelastic deformations of the glass at different temperatures are calculated by using the Maxwell model and the Arrhenius shift function; the mold material is treated as a purely elastic material.

Based on the thermal and structural models, a calculation algorithm for the whole process is built up. Which contains three phases, from analogical to the real molding process. First of all, the heating process includes a thermal and a
structural simulation. During the molding process, the structural calculation is divided into many substeps because of the large deformation in glass. The cooling phase is also simulated in both structural and thermal models, and the calculation is carried out in a program loop which contains different calculation steps with short time intervals.

Conclusions
The verification of a FEA simulation is shown in Figure 5. It is a molding process simulation of a plane-concave lens with an outer diameter of 18 mm and a form accuracy of 2 µm on the nonspherical surface. The insert material is tungsten carbide and the glass is crown glass B 270 of Schott AG. The comparison of the simulated and the measured glass lens geometry shows that a large form deviation up to about 12 µm is achieved in both the measurement and the simulated results, and the difference between these two curves is less than 2 µm. So the FEA simulation can be used for the mold design to reduce the mold making iteration and also to eliminate the pre-molding.

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References

FIGURE 6: Comparison of simulation result to the measurement of the molded lens